Transitions Pathways and Risk Analysis for Climate Change Mitigation and Adaptation Strategies

D2.1 – Tools and Procedures for Engaging Stakeholders in TRANSrisk Case Study Analysis

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Preface

Both the models concerning the future climate evolution and its impacts, as well as the models assessing the costs and benefits associated with different mitigation pathways face a high degree of uncertainty. There is an urgent need to not only understand the *costs and benefits* associated with *climate change* but also the *risks, uncertainties and co-effects* related to different *mitigation pathways* as well as *public acceptance* (or lack of) of low-carbon (technology) options. The main aims and objectives of TRANSrisk therefore are to create a novel assessment framework for analysing costs and benefits of transition pathways that will integrate well-established approaches to modelling the costs of resilient, low-carbon pathways with a wider interdisciplinary approach including risk assessments. In addition, *TRANSrisk* aims to design a decision support tool that should help policy makers to better understand uncertainties and risks and enable them to include risk assessments into more robust policy design.

PROJECT PARTNERS

No	Participant name	Short Name	Country code	Partners' logos
1	Science Policy Research Unit, University of Sussex	SPRU	UK	
2	Basque Centre for Climate Change	BC3	ES	
3	Cambridge Econometrics	CE	UK	
4	Energy Research Centre of the Netherlands	ECN	NL	
5	Swiss Federal Institute of Technology (funded by Swiss Gov't)	ETH Zurich	CH	
6	Institute for Structural Research	IBS	PL	
7	Joint Implementation Network	JIN	NL	
8	National Technical University of Athens	NTUA	GR	
9	Stockholm Environment Institute	SEI	SE, KE	
10	University of Graz	UniGraz	AT	
11	University of Piraeus Research Centre	UPRC	GR	
12	Pontifical Catholic University of Chile	CLAPESUC	CL	

Executive Summary

This purpose of this deliverable is to present an overview of tools that can be used for engaging stakeholders in participatory processes in TRANSrisk case studies. It supports the objective of TRANSrisk to integrate quantitative tools with qualitative tools so that the output of an analysis is not only based on aspects that can be quantified but also include qualitative aspects (e.g. stakeholder viewpoints and knowledge) that are more difficult to quantify while still being important for the eventual success of a decision. With the qualitative tools, stakeholders' tacit knowledge can be codified in order to support the development of low-emission pathways.

Much like the broad range of quantitative tools (models) we will be applying in TRANSrisk, we also have a diverse range of qualitative tools. We introduce 8 qualitative tools for engaging with stakeholders including: the Power and Interest Matrix, H-Form, Multi Criteria Decision Analysis (MCDA), Delphi, System Mapping, Fuzzy Cognitive Mapping (FCM) and Agent-based Modelling (ABM). We also intend to use the Online Multidisciplinary Information Management Software (OMIMS) to organise the diverse stakeholder inputs.

These tools described are grouped in three categories which correspond to the purposes of involving stakeholders in the TRANSrisk case study analysis (see also Figure 1):

1. Identify and prioritise stakeholders in an innovation system, such as for low-emission transitions;
2. Identify and categorise the preferences of different stakeholder groups; and
3. Describe and analyse systems for low-emission transition, including barriers to and enablers for innovation, for policy making support.

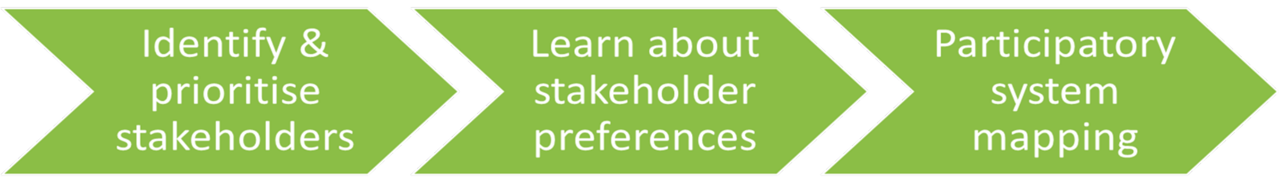

Figure 1. Categories of stakeholder consultation tools in TRANSrisk

In the first category, the **Power and Interest Matrix** is identified in this deliverable as a tool to prioritise stakeholders based on their legitimacy and saliency to influence decision or to be influenced by decisions. The prioritisation is based on stakeholders' attributes of power, legitimacy and urgency. Stakeholder power is defined as the capacity to which stakeholders apply pressure to initiate change. Using the matrix, stakeholders are described as actors with: low power and low interest; low power and high interest; high power and low interest; and high power and high interest.

In the second category, **H-Form**, **Multi Criteria Decision Analysis** (MCDA), **Delphi** and **Online Multidisciplinary Information Management Software** (OMIMS) tools have been

identified for the case studies in TRANSrisk. H-Form is particularly applicable for the first stage(s) of the case study analysis as it facilitates a discussion around focused (research) questions and organising the answers in categories with the objective to reach an agreement on further actions. MCDA help stakeholders to assess a range of climate change mitigation options against multiple criteria. This facilitates considering several perspectives of a decision making process so that eventually prioritised options achieved the highest combined benefits across the criteria considers. Similar to MCDA, OMIMS aims at homogenising a wide, heterogonous set of information about how a climate change mitigation option is valued by stakeholders against multiple criteria, using an online software tool. **Delphi** has been included in the overview of stakeholder preference identification tool as it supports analysis, such as in the TRANSrisk case studies, on longer term solutions for climate change mitigation and enables reaching agreement among stakeholders on these, both technology options and policy instruments.

In the third category, the main tool identified for the case study analysis in TRANSrisk is the **system mapping**. This highly participatory tool takes a prioritised option for climate change mitigation within a country as a starting point and then facilitates identification of the presently existing enabling (policy) environment for the option, the value chain with actors for processing the option towards implementation at a desired scale and facilitating services available in the country to support implementation of the option. With the resulting map, a system description is created which forms the basis for further analysis of whether and where in the system blockages exist for further innovation around the prioritised mitigation option and how these can be addressed.

Other system mapping or analysis tools identified for TRANSrisk stakeholder engagement are **Fuzzy Cognitive Mapping** (FCM) and **Agent-based Modelling** (ABM). FCM follows a similar approach as system mapping in the sense that it describes, with stakeholders, an innovation system or market with its elements or concepts and the connections between these. A key difference between FCM and system mapping is that FCM determines the level of causality that each relationship represents. It also performs simulations for stress-testing a number of alternative options for climate change mitigation within the system, which enables comparison between options in terms of their impacts on their system for implementation. ABM allows a disaggregated specification of actors in an innovation system and their heterogeneous traits, thereby considering local circumstances. The resulting model for the innovation system can be used to estimate, for example, which actors are likely to adopt a low-emission option, such as a technology, and at what scale. As a model, based on a bottom up description of the innovation system, ABM supports building bridges between the often micro-level focus of qualitative tools and macro-level level focus of most of the quantitative analytical tools within TRANSrisk.

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1 EC SUMMARY REQUIREMENTS

1.1 Changes with respect to the DoA

This deliverable is prepared in accordance with the DoA.

1.2 Dissemination and uptake

This deliverable will support the work in the TRANSrisk case studies, in particular the participatory consultations with stakeholders, to mobilise tacit knowledge of stakeholders in the case study countries and help integrate qualitative and quantitative analysis in TRANSrisk. Project partners are primary users of the deliverable.

More generally, beyond TRANSrisk, the deliverable can be used by any kind of environmental and/or climate change decision making process as the tools help to consider and integrate stakeholder knowledge and preferences in such processes.

1.3 Short Summary of results

This deliverable presents an overview of tools that will be used for engaging stakeholders in participatory processes in the case study analysis. It supports the objective of TRANSrisk to integrate quantitative tools with qualitative tools so that the output of an analysis is not only based on aspects that can be quantified and, for example, included in a quantitative model, but also on aspects that are more difficult to quantify while still being important for the eventual success of a decision. With the qualitative tools, stakeholders' tacit knowledge can be codified in order to support developing low-emission pathways.

The tools in this deliverable help to identify and characterise qualitative aspects that are important for addressing a specific problem. The tools are all focused on stakeholders' behaviour, their preferences, how they interact in a market or system and how all these aspects have an impact on the eventual effectiveness and efficiency of a policy.

We introduce 8 qualitative tools and 1 software management tool in this deliverable. The tools are grouped in three categories which correspond with the purposes of involving stakeholders in the TRANSrisk case study analysis:

1. Identify and prioritise stakeholders in an innovation system, such as for low-emission transitions;
2. Identify and categorise the preferences of different stakeholder groups; and

3. Describe and analyse markets or systems for low-emission transition, including barriers to and enablers for innovation, for policy making support.

1.4 Evidence of accomplishment

Delivery of the deliverable on 29 February 2016.

2 Introduction

This purpose of this deliverable is to present an overview of tools that can be used for engaging stakeholders in participatory processes as foreseen in the case studies and other analytical steps in TRANSrisk. It supports TRANSrisk's objective to integrate quantitative and qualitative tools. Integration will ensure that the output of an analysis is not only based on aspects that can be quantified, but also includes qualitative aspects (e.g. stakeholder viewpoints and knowledge) that are difficult to quantify yet still important for the eventual success of a decision. For example, while a quantitative model is able to quantify what the outcome of policy may be based on quantitative aspects, it may not be able to consider people's preferences or market barriers as these are more difficult to quantify.

Much like the broad range of quantitative tools (models) we will be applying in TRANSrisk, we also have a diverse range of qualitative tools that could be used to capture stakeholder opinions, preferences and (tacit) knowledge. The tools will not all be simultaneously applied to each case study, but will be selected based on the stakeholder engagement process and applied in different data collection methods. The qualitative data collection methods in TRANSrisk include interviews (~1-2 people), smaller focus groups (~2-8 people), stakeholder workshops (~8-20 people) and surveys (~20-1000 people).

In this deliverable, we introduce 8 qualitative tools for engaging with stakeholders including: the Power and Interest Matrix, H-Form, Multi Criteria Decision Analysis (MCDA), Delphi, System Mapping, Fuzzy Cognitive Mapping (FCM) and Agent-based Modelling (ABM). We also intend to use the Online Multidisciplinary Information Management Software (OMIMS) to aggregate the diverse stakeholder inputs to assist with analysing the content.

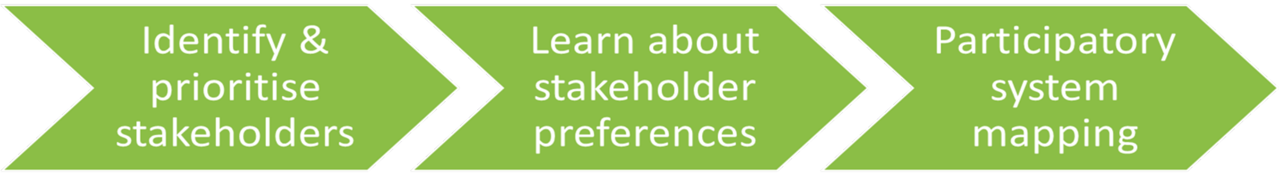
The tools have a common objective of identifying and characterising qualitative aspects that are important for addressing a specific problem. The tools are all focused on stakeholders' behaviour, their preferences, how they interact in a market or system and how all these aspects have an impact on the eventual effectiveness and efficiency of a policy. With the qualitative tools, stakeholders' tacit knowledge can be codified in order to support the development of low-emission pathways.

Partners have had exposure to the tools during the kick-off meeting and on-line meetings over the past 6 months. We will provide practical training for these tools during a workshop in Athens on 9-10 March 2016 and additional on-line workshops will be carried out on an as needed basis.

The tools in this deliverable are grouped in three categories which correspond with the purposes of involving stakeholders in the TRANSrisk case study analysis (see also Figure 2):

1. Identify and prioritise stakeholders in an innovation system, such as for low-emission transitions;
2. Identify and categorise the preferences of different stakeholder groups; and
3. Describe and analyse markets or systems for low-emission transition, including barriers to and enablers for innovation, for policy making support.

Figure 2. Categories of stakeholder consultation tools in TRANSrisk



In the first category, the Power and Interest Matrix prioritises stakeholders based on their legitimacy and saliency to influence decision or to be influenced decisions. Tools in the second category are used to assess climate change mitigation solutions against multiple criteria (multi-criteria decision analysis) or to investigate an issue through exploring a core question and identify actions to be undertaken to move forward. Tools in the third category support analysis of the relevant (market) system for an identified solution for mitigation, including an assessment of the enabling environment for the system, analysis of the actors active in the system and how they interact, and where and to what extent system barriers to successful implementation of the mitigation option exist. The tools in this category vary from qualitative to semi-quantitative, whereby the latter tools aim at quantifying interactions between system actors and using this to model responses of actors to climate change mitigation decisions.

The overview of tools for participatory processes to support qualitative analysis in TRANSrisk case studies is not exhaustive, but has been compiled on the basis of familiarity and experience of TRANSrisk partners with the tools. In chapter 6 of this Deliverable, an overview is presented of possible application of the qualitative tools in TRANSrisk workpackages. It is noted that some of the tools have been specifically included in the description of TRANSrisk workpackages in the Grant Agreement, such as Multi Criteria Decision Analysis, System mapping, Fuzzy Cognitive Mapping and Agent-based Modelling. Other tools explained in this Deliverable are optional and have been identified by partners as potentially supportive of steps in the case study analysis, such as: H-Form to facilitate a

generic discussion during the first stage of a case study, Delphi for an alternative type of decision-making against multiple criteria and the Online Multidisciplinary Information Management Software tools as an alternative multi criteria analysis tool. Their application will be decided on during the case study preparations.

This deliverable complements the deliverable D2.4 (Stakeholder Engagement Plan), which provides the detailed steps to carry out the stakeholder engagement. As both deliverables are strongly connected, D2.4 will be delivered early so that the package of D2.1 (tools) and D2.4 (processes) is available on time for the preparation and analysis of the case studies, which will start in April 2016.

3 IDENTIFY AND PRIORITISE STAKEHOLDERS

3.1 Power and Interest Matrix

In TRANSrisk deliverable D2.4 procedures for (Parboteeah & Cullen, 2012) the identification of stakeholders for the case study analyses are explained. Partly, these identified stakeholders are 'generalists' who have an overview of all issues at stake and can advise the project partner. Other stakeholders are specifically identified for a particular stage in the case study process as they have detailed, hands-on, practitioners' knowledge of issues at stake in the case study analysis.

In this section, the Power and Interest Matrix (See Figure 3) is described as a tool to prioritise stakeholders based on their legitimacy and saliency to influence decision or to be influenced by decisions. The power and interest matrix is primarily designed to identify and prioritise stakeholder as part of a firms' stakeholder management strategy (Parboteeah & Cullen, 2012). The prioritisation is based on stakeholders' attributes of power, legitimacy and urgency. Stakeholder power is defined as the capacity to which stakeholders apply pressure to initiate change. Stakeholder power can be coercive (using force or violence), utilitarian (financial influences) or normative (symbolic expression such as social media) (Parboteeah & Cullen, 2012). Stakeholder legitimacy is determined by societal acceptance while urgency or saliency is 'intensity of claim, attention and priority attached to a stake (Chinyio & Akintoye, 2008). Power and urgency changes over time, particularly if stakeholder coalitions are formed, thus should be appropriately monitored.

The Power and Interest matrix helps to prioritise the actions required for different groups of stakeholders within the system:

- **Stakeholders with low power and low interests** are not highly influential or greatly impacted by the changes or recommendations from TRANSrisk, but still hold a stake in delivering the project outcomes. Communication activities can usually be limited to, for example, mass communication or newsletters. These stakeholders should be monitored with limited effort and responded to on an as needed basis.

- **Stakeholders with low power and high interest** are significantly affected by the outputs of TRANSrisk but have less influence over others and less potential to disrupt the process. These stakeholders should be kept informed regularly about the project and communication should be strong, pro-active and pre-emptive. If possible, more influential stakeholders (see below) could be used to influence the acceptance or adoption of the project's findings by this stakeholder group.
- **Stakeholders with high power and low interest** have significant influence over other stakeholders and are therefore important for dissemination of the project's results and recommendation to wider stakeholder groups. It is important to anticipate their objections and adverse reactions when planning communications between the project and wider stakeholder groups, but the main requirement is to keep these stakeholders satisfied during the project (e.g. their requirements in the stake are fulfilled). This requires that communication with stakeholders should be maintained but this does not need to be as resource-intensive or frequent as with the key players described below.
- Finally, **stakeholders with high power and high interest** should be monitored closely. They are highly influential for the success and communication of TRANSrisk case studies and results. Moreover, the outputs of TRANSrisk will have significant impact on their future activities. Communication with these stakeholders is aimed to involve them closely in project steps with frequent personal contact and face-to-face communication.

Figure 3. Stakeholder Power and Interest Matrix

		Interest (saliency)	
		Low	High
Power	Low	Minimal effort - respond when necessary	Keep informed regularly
	High	Endeavour to keep satisfied	Constantly manage key players

4 Learn About Stakeholder Preferences

4.1 H-Form for Identifying Stakeholder Views and Formulating Actions

4.1.1 Context and Purpose of the (original) Application of the Tool

The **H-form** is an analysis tool that was initially designed by (Guy & Inglis, 1999) to structure workshop participants' thinking, facilitate monitoring and evaluation exercises and generate ideas around a specific question. The tool aims to help both individuals and groups to record their own views and ideas on a structured, open, but non-threatening way throughout meetings, conferences, workshops, etc. The H-form also enables to keep discussions focused and specific, to reach consensus and develop action points that could be considered in the future.

The H-form exercise is generally conducted in small groups (4-8 people) to propose, discuss and prioritise individual ideas following the 5 fundamental steps of this method (see below).

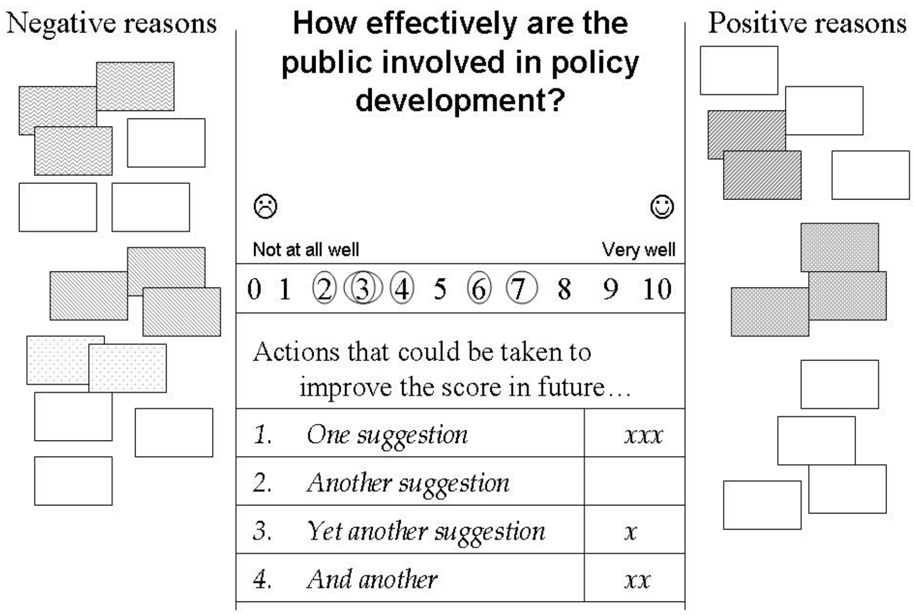
4.1.2 Analytical Focus and Theoretical Basis

As mentioned above, the tool focuses on assessing a specific question based on stakeholders` input. The H-form tool consists of 5 key steps:

1. Participants – individually - consider a given question. They are provided with a negative and a positive answer to the question that represent opposite ends of a 0 to 10 scale, which they use to provide a numerical response to the question.
2. Participants – individually - explain the (both positive/negative) reasons of their score.
3. Discuss these positive and negative reasons as a group and cluster similar points and views.
4. Suggest actions – individually – that could be considered to improve future scores.
5. Rank the suggested actions by voting.

The outputs of each stage of the exercise are demonstrated on designated areas of large paper templates that are handed out to participants at the beginning of the exercise. An example of such H-form can be seen in Figure 4.

Figure 4. Diagram of a completed H-form (each x represents a vote)



With the assistance of a facilitator, specific instructions are given to participants to work through the form, with a time limitation for each task.[1] Participants may write any additional comments, concerns and assumptions on a commentary card provided separately by the facilitator.

The exercise can be also extended by integrating an **action planning** element as a 6th step to the 5 steps above. Action planning aims to process and transform the outputs of the H-form exercise into a concrete plan of action. This requires the selection of high priority action ideas (e.g. how to improve participation of public in regional developments or policy development), grouping of similar ideas and participants` discussion into small groups focusing on the practical aspects of these actions. The following Table 1 can be used to develop action plans based on the outcome of the H-form exercise.

[1] A detailed example on instructions for participants can be found in (Hunsberger & Kenyon, 2008, volume 4, Issue 1, Article 1).

Table 1. Action planning table following from an H-form

Action	Why?	Who should do what?	How?	When?	Done!
Actions from H-form	Why is it important?	Who should be responsible for what, to make it happen?	How can they do it or encourage it to happen? Using what resources?	When should it be done?	How will we know when it is done?
1					
2					
3					
4					

With these action plans various groups of key actors (e.g. researchers, policy makers and other public and private stakeholders) can be approached with concrete priority ideas and recommendations for future improvements.

Similar to system mapping, H-form is based on the assumption that participatory processes can mobilise a broad range of (professional and/or anecdotal) knowledge available among stakeholders in a market, sector or country. H-form exercises with stakeholders can be conducted with a skilled facilitator who should stimulate participants to share their knowledge and insights in a structured manner (using the previously developed paper templates). The process has a clear objective (e.g. evaluate how well objectives are being met or how much are the public involved in regional developments etc.). The hypothesis is that the tool helps to bring to the fore both knowledge that can be measured as facts and perceptions that exist among stakeholders. Through the exercise such facts can be shared among stakeholders and perceptions where necessary amended based on new insights.

4.1.3 Sources, Types and Processing of Data

The main data source for the H-form exercise is stakeholders' knowledge and (professional) experience. The H-form technique helps organise the knowledge and prioritise views for the next steps. The formulation of the research questions is a careful process since these might be context dependent and in addition could be more relevant to some participants than others. Therefore, the questions must be stated clearly to avoid long discussions at the beginning of the process and remain in the time-limited settings as originally planned. Also the potential presence of `saboteurs`, who are not willing to participate in the exercise (often for a valid reason) and hence disrupting the exercise process (Kenyon & Hunsberger, no year) needs to be considered. Before handing out the forms, it is therefore wise to remind participants that the exercise is constrained and might contain potential problems that could be addressed on the provided commentary sheets. As a last resort, a blank H-form might be provided for those who do not like the research question. This way these participants can devise their own question and complete the form according that question.

Figure 5. Conference participants completing the H-form

Source: (Kenyon & Hunsberger, no year)

4.1.4 Applicability within TRANSrisk

H-form could be used in TRANSrisk for the evaluation of a wide range of topics or questions from the perception of stakeholders (e.g. status of objectives, financial effectiveness of an investment, involvement of public in decision making and regional developments, satisfaction of services, level of local economy benefits etc.). H-forms can be used to stimulate people of all ages in a participatory exercise, and used in combination with other tools such as mapping and timelines. It may also help facilitate the first step in the case study analyses where stakeholders will be given a set of research questions. H-form technique can help organise the answers and prioritise views for the next steps.

4.1.5 Value of the Tool for Stakeholder Engagement

When applying H-forms, the envisaged result is to evaluate research questions (see above). This also includes an overview of potential barriers and inefficiencies, formulating ideas and suggestions for future improvements and if action planning is part of the exercise, concrete plans can be developed to implement these ideas and recommendations. For example, using H-forms and action planning enables stakeholder groups to explain how to engage the public more effectively in project developments, how to tackle public acceptance problems or improve effectiveness of climate policies. For environmental and social policy impact assessment the questions to be asked might be:

1. How efficient is a policy to reach the environmental target and what are the opportunities/ideas/recommendations to improve this policy and reach the original policy target?

2. What is needed in our (case study) country to enable scaling up of a mitigation option to a desired scale?
3. What could be the consequences for power grid stability in our country if we penetrated this renewable energy technology at its technical potential?
4. How the public can be more effectively involved in regional project developments?

Therefore, H-form can help assess whether an environmental/social impact has been or has not been achieved and help explain the reason for this result (by stating negative and positive reasons on the form). Conclusions of the H-form exercise are mostly represented qualitatively but as the stakeholders score their views on a scale of 0 (negative) to 10 (positive), inputs to the conclusions are also partly based on semi-quantitative data collected during the exercise.

The H-form exercise can help to draw conclusions on whether a desired goal has been achieved (effectiveness) with a particular policy instrument. In addition, stakeholders can explore whether this impact has been achieved with lowest possible resources or whether a better outcome could have been reached with the same resources (efficiency). Finally, it can be explained what has caused these results.

H-form and action planning are useful tools in terms of stakeholder mobilisation and mobilisation of stakeholders' expert knowledge. Therefore, upfront data requirements are relatively low. The tool fosters both individual expression and common understanding. It is also useful in terms of addressing and evaluating a wide range of research questions with the assistance of a skilful facilitator. Since the idea is to work in multiple small groups, this tool is ideal to develop a list of prioritised action ideas and recommendations that can be fed into a concrete plan of action. The tool is not applicable to assess research questions that are vaguely formulated (they have to be rather specific to sufficiently work).

4.2 Multi Criteria Decision Analysis (MCDA)

4.2.1 Context and Purpose of the Application of the Tool/ Method

Multi Criteria Decision Analysis (MCDA) aims to consider the scope of analysis beyond a single or a few impact dimensions to multiple dimensions. Based on participatory and deliberative approaches the tool aims at balancing different opinions that stakeholders may have and work towards agreements. The primary aim of this method is therefore to provide greater analytical rigour and provide the ability to 'close down' policy debates compared to the conventional deliberative methods (e.g. citizens' juries or panels, consensus conferences, future search, deliberative polling). At the same time MCDA helps

to 'open up' the analysis through exploration of the complexities of the issue, and allowing for considering incommensurability of values -features that conventional expert-based methods such as cost-benefit analysis and monetary environmental evaluation fail to deliver.

The main idea of MCDA is that stakeholders in a participatory setting, such as a workshop, consider a range of options, e.g. technologies for climate change mitigation, and assess these against a set of criteria. These criteria can be pre-defined, such as economic, social and environmental development and contribution to greenhouse gas emission reduction, but can also be discussed before the MCDA starts by the stakeholders themselves. This enables them to pose locally- or country-specific (research) questions and put emphasis on aspects they find important, such as health improvement, energy security or poverty alleviation.

Once criteria are defined, each option (*e.g.* technology) is assessed by the stakeholders by scoring how well or poorly an option contributes to meeting a criterion. Scoring can be done in different ways, but a conventional way is to use a relative scoring table from 0-100 whereby 0 means that an option is least preferred against that criterion while a score of 100 means that the option is most preferred. A score of 0 does not mean that the option has no benefit, but that among the options considered it delivers the lowest benefits. On such a relative scale, all other options are scored relative to the most and least preferred. In other words, an option which receives a score of 50 is assumed by stakeholders to deliver the benefits that are halfway between those of the most and least preferred options.

For example, if we consider four technology options - wind, solar, biogas and hydropower – and stakeholders conclude that development and transfer of biogas will generate most jobs in the country (1000), hydropower the least (500) and solar (600) and wind (750) in between of that, then the following scores result:

- Biogas 100
- Wind 50
- Solar 20
- Hydropower 0

This scoring is repeated for all criteria, so that a scoring table results (Figure 6).

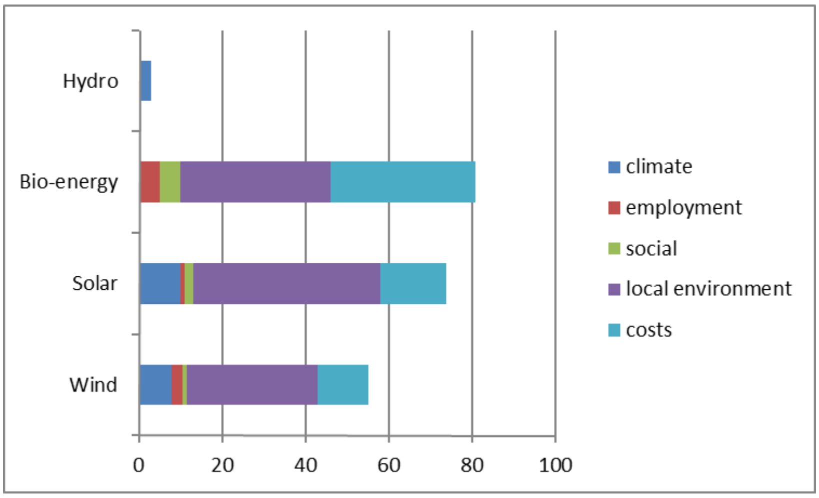
Figure 6. Scoring climate options against multiple criteria

Technology options	Climate benefit: - mitigation, or - adaptation	Employment generation	Social benefits	Local/ national environmental benefits	Costs
Wind	80	50	20	70	35
Solar	100	20	40	100	45
Bio-energy	0	100	100	80	100
Hydro	30	0	0	0	0

Based on these scores, no decision can be taken yet, as the scores cannot be simply added up across the criteria. The reason for that is that stakeholders may find some scores more important than others. For example, in the above example, all technology options will generate jobs (at least 500). At the same time, stakeholders may conclude that the difference between, for example, the most and the least preferred options against local environmental benefits is very big (e.g. positive impact of solar panels versus a negative local environmental impact of hydro plants). Then, stakeholders may conclude that, given this assessment, the criterion of local environmental benefits requires a higher weight (to make sure that the negative environmental impact of hydro counts importantly in the final decision). Similarly, no high weight may be considered necessary for employment generation (i.e., all options will generate jobs). In other words, the weighing of criteria takes place by comparing the least and most preferred options for each criterion and deciding how important this difference is considered to be. The results after weighting the scores are shown in Figure 7, which shows that, based on stakeholder preferences, bio-energy is the most preferred technology within the country.

Figure 7. Cumulative weighted scores

Technology options	**Climate benefit: - mitigation, or - adaptation**	**Employment generation**	**Social benefits**	**Local/ national environmental benefits**	**Costs**
Wind	80	50	20	70	35
Solar	100	20	40	100	45
Bio-energy	0	100	100	80	100
Hydro	30	0	0	0	0
Weight (0-100)	10	5	5	45	35
cumulatative weighted scores					
Wind	8	3	1	32	12
Solar	10	1	2	45	16
Bio-energy	0	5	5	36	35
Hydro	3	0	0	0	0



4.2.2 Analytical Focus and Theoretical Basis

MCDA focuses primarily on assessing options (e.g. policy, technology) in support of decision making, by helping stakeholders map the impacts of options, consider trade-offs and synergies between options, value conflicts and address uncertainties. MCDA supports collecting and categorising information about several possible options so that stakeholders can assess for a range of criteria which option is most preferred with respect to a criterion and how other options score relative to the most preferred one.

Aspects of focus, in terms of criteria, depend on the country or decision context. As explained above, criteria can be general and pre-determined, but may well be topic of consideration by stakeholder before the MCDA starts.

The basic hypothesis underlying the method is that the stakeholder group obtains a clearer picture of what works best, and what works less well, if they can compare options in relation to each other (instead of evaluating them one by one, individually). Based on this picture the group can conclude that option X is expected to contribute most strongly to reaching environmental target and policy instrument Y is least preferred, and that the impact of policy instrument Z is about half as large as that of instrument X. The rationales for these conclusions based on the group discussion are also collected in an MCDA as an audit trail.

An important characteristic of MCDA in comparison to cost-benefit analysis is that it does not require monetization of the benefits, which often complicates cost-benefit analysis as not all benefits can be quantified and/or expressed in monetary values (UNDP, 2010). MCDA avoids pure quantification of benefits by capturing qualitative inputs and scoring them using a relative scale. The (qualified) benefits to costs preferences can be presented generally in two ways:

- Represent cost preferences: the monetary values of costs are expressed, similar to qualifying the benefits, along a relative scale of 0-100, whereby the costliest option receives a score of 0 and the cheapest option receives a score of 100 (as done in the examples in Figure 6).
- Confront quantified costs with qualified benefits in a Cost-to-Benefit ratio and rank options based on the highest ratio of benefits to the costs (see Figure 8).

Figure 8. Example of ranking of options based on ratios of benefits to costs.

It is also considered important from an MCDA perspective that these criteria are weighted *after* the scoring has taken place (through pair-wise comparison or swing weighting), as explained above. This enables stakeholders to weight options within their decision context. For example, if the difference between the most and least preferred policy option is small, stakeholders may conclude that choosing option x or y would not make much difference on overall performance for the criterion. This could be reflected by a low weight.

It is clear that the process of scoring and weighting the impacts of policy instruments within a decision context by a group of stakeholders is to a large extent subjective. Where impacts can be quantified, no subjective decision will be required from stakeholders (quantified data for policy instruments are reformatted in the tool into relative scores from 0 to 100). However, where subjective opinions form the basis for the decisions, the tool has the strength that it makes these explicit, by addressing uncertainties through sensitivity analysis.

4.2.3 Sources, Types and Processing of Data

As explained above, the main steps in an MCDA are:

1. Identification of the policy or technology options for climate change mitigation to be analysed in the MCDA.
2. Definition of criteria against which the options are to be appraised.
3. Assignment of scores to the different options, against the criteria defined in Step 2.
4. Assignment of weights to the criteria, by comparing for each criterion the actual difference between the most and least preferred options and deciding how important these differences are.
5. Exploration of uncertainties through sensitivity analysis.
6. Ranking of options based on cumulative weighted scores and/or benefit-to-cost ratios.

This implies that two types of data are used in an MCDA:

- Knowledge of options to be considered in the MCDA, such as technology costs, jobs needed to transfer the technology, infrastructure requirements, number of households to be served, etc.
- Standpoints, worldviews, assumptions, as well as tacit knowledge of stakeholders.

The information about options is usually presented to stakeholders in easily digestible forms, such as fact sheets, which enables stakeholders to quickly understand the key figures and facts for each option. Based on this knowledge, stakeholders use their standpoints, worldviews and assumptions to value the contribution of each option in terms of multiple benefits and costs, using the scoring and weighting process explained above.

Should the MCDA not be conducted in a participatory workshop environment, then interviews can be used instead. Interviewees view the results of the exercise on a computer-generated graph, with the relative ranking of each option. The participants can evaluate their rankings for themselves and consider any surprises in light of the process they have worked through. They can review the information until they are comfortable that all pertinent issues have been taken into account, and that the pattern of performance displayed in the option rankings fully reflects their own perspective.

4.2.4 Applicability within TRANSrisk

In TRANSrisk, transition pathways are developed for which decisions need to be made about what options for climate change mitigations to include in the pathway and at what scale. MCDA is an applicable tool for that as it helps to assess the pros and cons of each option within the decision context of the pathway development. The advantage of the tool is that it supports an active stakeholder consultation and discussions among stakeholders, and avoids the need to monetize benefits.

A potential negative aspect of MCDA participatory discussions to be considered in TRANSrisk case studies is that stakeholders may disagree about the scores and weights, making it difficult to reach an agreement. One way to mitigate this risk is through a good facilitator, but even then disagreements may continue to exist. Another way, then, is to first move on with the assessment based on one opinion and, once completed, repeat the assessment from the point where that disagreement arose and continue with the other opinion. Once completed, both assessments can be compared which will show the impact of the disagreement on the final prioritisation result. For example, it may well be that the disagreement has no impact on the final result. Sensitivity analysis, which is often part of an MCDA, among others to deal with uncertainties, can support the handling of disagreement.

4.2.5 Value of Tool for Stakeholder Engagement

By drawing attention to the diversity of perspectives from which policies can be assessed, MCDA draws attention to assumptions that might otherwise be taken for granted in a decision making process. MCDA also helps to deal with a recurrent problem faced in policy assessment, that is, the reluctance of some stakeholders to engage in a quantitative assessment of options, based on a one-dimensional assessment criterion. Rather than providing straightforward unambiguous answers concerning the performance of a policy, MCDA represents a 'heuristic' approach that permits to 'map' the debate concerning the policy in question, including the identification of issues of consensus and controversy among stakeholders (Stirling & Mayer, 2001).

An important asset of MCDA is that enables integration of stakeholders' (tacit) knowledge, viewpoints and standpoints in a decision making process and codifies their knowledge, even though not all or only a few of these knowledge types can be quantified.

When using MCDA, it is acknowledged that decision making is not fully objective and largely determined by subjective considerations. A benefit of using MCDA is that it makes these subjective considerations explicit, and records these in an audit trail.

MCDA can easily be performed in an Excel-type of environment, which allows for visualisation of the impact of considerations and decisions.

The limitations of MCDA stem in particular from its relative complexity and resource-intensity. Rather than being a standalone method for judging the relative worth of policy options, MCDA can be used for instance as part of deliberative appraisal processes, in order to provide analytical rigour discipline, transparency, and verifiability.

4.3 Online Multidisciplinary Information Management Software

4.3.1 Context and Purpose of the (original) Application of the Tool / Method

Online Multidisciplinary Information Management Software (OMIMS) is a cross-platform web-based software tool that enables the analyst to assess heterogeneous information, regardless of the number or nature of the evaluation criteria and the number of alternatives. During a stakeholder engagement process, experts may find it hard to express their preferences directly as numeric values that are easily processed; instead, they may provide part of their input in the form of linguistic information or intervals. OMIMS features the options of:

- Unifying all heterogeneous information into the same term set.
- Aggregating the information, in order to evaluate and compare different alternatives.
- Visualizing the results.
- Sharing both the data and the results among the analysts.

Within TRANSrisk, OMIMS could be applied in tasks of any Work Package, where either stakeholder engagement or multiple and non-homogeneous criteria decision making is required.

4.3.2 Analytical Focus and Theoretical Basis

OMIMS focuses on the assessment of the examined options against a respective set of criteria. The process for structuring the problem and ranking different options, e.g. scenarios, technologies, pathways, etc., needs a transparent methodological framework for heterogeneous data aggregation that can be easily and equally understood by both involved stakeholders and analysts. The proposed web platform can address this issue adequately, and can also create benchmarks based on the input from different stakeholders, for different sectors and/or countries.

OMIMS is based on the '2-tuple' (pair-wise) representation model that Herrera et al. (2005) developed in order to manage non-homogeneous information. The tool first transforms numerical values, linguistic information and interval values into the same linguistic domain by using fuzzy sets. It then aggregates the unified information into a 2-tuple, an expression model that consists of a linguistic term (within a user-predefined range of terms) and a numerical value within the range [-0.5, 0.5).

The tool's main advantages are highlighted in multiple-criteria problems, where each criterion is of different nature. Additionally, OMIMS can be equally effective in Group Decision Making, which is the case with multiple stakeholders: each stakeholder may choose to address the same question differently and answer in numerical, interval or linguistic values. In this case, the aggregation of all stakeholders' inputs may be achieved using OMIMS, by unifying all heterogeneous answers into the same term set.

4.3.3 Sources, Types and Processing of Data

OMIMS can organise any heterogeneous information that must be aggregated in the context of TRANSrisk, either provided by stakeholders or by other means (e.g. secondary research).

Initially, the analyst defines the linguistic scale in which they want the problem to be solved, since variables of this scale will be used to express the 2-tuple model. Decision variables and alternatives must then be defined, along with the type of information each variable corresponds to (interval, numerical, linguistic).

After the problem has been modelled, all information is unified into the same Basic Linguistic Term Set. Having completed the unification phase for each alternative, all variable values are aggregated into one final, unique set, which is later transformed into a 2-tuple representation, making alternatives comparable.

4.3.4 Applicability within TRANSrisk

Stakeholder participation is a key part of every Work Package throughout the TRANSrisk project. OMIMS could be used in TRANSrisk for the purpose of facilitating the team of

researchers to assess heterogeneous information provided by stakeholders. The tool could also be used for sharing decision making problems with multiple criteria among partners.

The OMIMS tool could be applied, after appropriate customization, in stakeholder-driven tasks, such as Task 5.4, Task 5.5 and Task 7.1, but it could also be applied in other Work Packages as well. For example, OMIMS can be applied when evaluating possible policy instruments in Work Package 3 that could be later incorporated into the quantitative models. It is underlined that the current version of the tool is a generic platform, which needs modification to be appropriately employed within the TRANSrisk project.

4.3.5 Value of the Tool for Stakeholder Engagement

OMIMS is a powerful tool that can be of important value for structuring the problem and assessing non-homogeneous information. By means of the 2-tuple representation model, numerical, linguistic and interval data can all be processed without any loss of information. It also provides partners with a user-friendly platform through which the same problems can be accessed, modified and solved by multiple users. For the time being, however, and prior to further customization, it can only process numerical and interval information of the same scale, i.e. [0, 1].

4.4 Delphi method

4.4.1 Context and Purpose of the (original) Application of the Tool/Method

The Delphi method is a structured communication method that was originally developed in the 50`s by the RAND Corporation to estimate the likelihood and occurrence of future events and, later, to examine and discuss specific issues for the purpose of goal settings and policy investigations (Rand Organisation, 26). (Hsu & Sandford, 2007). This long-range forecasting (20-30 years) is based on anonymous survey data (e.g. independent estimates and assumptions on a certain future event) obtained from a panel of experts in two or more rounds. The survey data is reviewed by a facilitator who issues a summary report. The results of the first round as a statistical representation of the group response are provided to the participants before the second round, allowing them to re-evaluate their original assessments or stick to their first opinion. The process repeats itself till the range of responses is reduced and a close consensus is achieved within the expert group on a specific real-world issue.

4.4.2 Analytical Focus and Theoretical Basis

The Delphi method focuses on handling disagreements among stakeholders or stakeholder groups that formulate opposing views by providing an iterative discussion platform with the ultimate goal of convergence and solutions. The method consists of the following steps:

- Choose a facilitator that is familiar with the research and data collection (yourself or a neutral person within your organisation).
- Identify the panel of experts (any highly trained individual with relevant knowledge and experience on the target issue). The optimal number of experts never reaches consensus in the literature. The number of participants can vary between 10 and 50, depending on the differences in participants` background. If the background of the participants is homogenous, 10 to 15 experts could be considered representative for the study. In case of dissimilar backgrounds, however, more participants need to be involved.
- Define the problem: provide a precise and comprehensive description on the issue that needs to be assessed.
- Question rounds: in the 1st round, specific research questions are shared with the panel of experts in the form of a questionnaire or a survey. The facilitator summarises the experts` forecasts, including the reasoning they provided for their expert judgment. In the 2nd round, ask participants to review the summarised items and in light of the responses of the expert panel encourage them to reassess their original opinion (if necessary) or specify the reasons of still opposing the consensus. Rounds are repeated untill a close consensus is achieved. Three iterations are generally sufficient to collect the desired information and reach consensus.
- Act on the findings: at the end of the exercise the hope is to obtain an expert view on future occurrences. After analysing the findings, recommendations can be made to deal with future risks and opportunities relevant to the project.

The Delphi method is based on the principle that forecasts or decisions provided by a structured expert group are more accurate than those from an unstructured group. Selecting the appropriate experts is the key element to ensure the quality of the results obtained with this method. With the aid of a skilled facilitator, the method can take place within the following settings:

- Surveys to a group of stakeholders via e-mail, with closed or semi-closed questions, so that most of the answers are provided via a Likert scale type of scoring (e.g. from -2 to 2), while allowing stakeholders to add comments in specific boxes (e.g. ‘other’).
- Bilateral interviews with stakeholders (phone or in person), with closed or semi-closed questions (largely similar to previous option).

- Bilateral interviews with stakeholders with open questions, which allow for more detailed, in-depth question-answer interactions with retrieval of anecdotal information.

The facilitator can stimulate participants to share their knowledge and insights in a structured way as well as summarise the results and research findings. The process has a clear objective to find consensus on possible future impacts (e.g. prioritisation of climate mitigation options). The hypothesis is that the tool helps to bring to the fore both knowledge and perceptions that exists among stakeholders. Through the Delphi method such information can be shared among stakeholders and perceptions, where necessary, amended based on new insights to converge towards a general opinion on future impacts.

The Delphi method can be applied in various fields such as needs assessment, policy determination, resource utilization and program planning. It can help develop a range of possible program alternatives, explore underlying assumptions and correlate judgments on a topic spanning a wide range of disciplines. Depending on the complexity of the problem, Delphi method can also be used for prioritising climate mitigation options, instead of the more elaborate and robust MCDA tool. Here stakeholders consider a few options and organise discussions around cost and benefits so that they converge towards a common opinion on options.

Confidentiality and anonymity of participants are two of the major advantages of this method. Using online tools reduces the impact of dominant individuals and the potential of group pressure for conformity that is often a concern in the setting of group-based exercises (e.g. workshops). On the other hand, experts might still change their views if they receive a distorted feedback from the facilitator/investigator. This potential for moulding of opinion could be minimised by evaluating experts` input data without bias during the development of the feedback summary report.

Participants only give their expert estimations that are presented as data and therefore the major risk is to regard this information as facts. Information about the future however never can be regarded as facts, only as predictions that often do not materialise due to the large number of variables (political, environmental, economic and social) that can change throughout the course of 20-30 years.

Also the number of experts and time requirements need to be carefully considered. If the participation is too low, the outcome might not be considered as a representative opinion on the target issue. In contrast, too large participation could give rise to the possibility of low response rates and unintentionally guiding feedback from the respondent group. Conducting a Delphi study might be a time-consuming exercise due to its iterative nature (several days or weeks may pass between each round). This might not be very attractive for experts that are often time constrained and already taking part in other studies and workshops next to their daily activities.

4.4.3 Sources, types and processing of data

The main data source for the Delphi method is stakeholders' knowledge and (professional) experience. The data obtained from these experts can involve both qualitative and quantitative data. Qualitative data is obtained when open-ended questions are used to extract stakeholders` opinion and views on the target issue. Whereas statistical tools such as means, medians and modes are used to measure central tendency and standard deviation and inter-quartile range to illustrate the level of dispersion of experts` responses.

4.4.4 Applicability with TRANSrisk

This method can be applied to predict the occurrence of various future events including the expected impact of environmental policies and climate change mitigation options. The Delphi method was first applied in the field of science and technology to combine experts` opinion on the likelihood and expected development time of a particular technology. Later, the method was also applied to tackle certain policy issues such as economic trends, public health and education, business forecasting and implementing multi-stakeholder views in policy-making processes. Therefore, the method can be used in the policy formulation stages to forecast the impact of the policy, determine desirability, feasibility (both technical and political) and probability, but also identify potential inefficiencies and barriers.

Within the context of TRANSrisk, Delphi can be a suitable tool in the case study analyses as it enables reaching agreements among stakeholders on a longer term vision or decision-making with a longer-term perspective. This characteristic can be especially useful during the first step of the case study participatory discussions when stakeholders are invited to express their preferences for climate change mitigation options, taking a wider, longer time perspective. The tool can also help for agreeing on options for climate change mitigation and policy instruments in WP3.

4.4.5 Value of the Tool for Stakeholder Engagement

When applying the Delphi method, the traditionally envisaged result is to obtain expert views and reach consensus on the most probable future occurrences. For more specified cases, such as policy making, Delphi becomes a decision support method which aims at structuring and discussing the various opinions of experts of the preferred future. Delphi method also allows exploring opportunities from and impacts of developing climate change mitigation options. Similarly, when using this method for policy assessment evaluation, it would enable expert groups to explain how a policy measure would work in the future in terms of achieving an environmental goal as well as what might be the risks and/or unintended effects in terms of economic and social impacts. For environmental policy impact assessment, the questions to be asked are: which are the most effective climate

change mitigation options that support reaching the policy target and what are the barriers for the mitigation options that could prevent to reach the desired environmental target. Therefore, the Delphi method can help assess whether an environmental impact will be achieved and help explain the reasons behind this judgment. Conclusions of this method can be both quantitative and qualitative, depending on the factor to be explained. However, in practice, Delphi outcomes and descriptions are mostly qualitative.

The Delphi method helps to foresee whether a desired impact will be achieved (effectiveness) with the aid of a particular policy instrument or climate change mitigation option. In addition, experts can explore how this impact could be achieved with the lowest possible resources or whether there are better options to reach a better outcome with the same resources (efficiency). Finally, it can be explained why certain options are prioritised and what are the potential risks and barriers that would prevent to reach the desired goal.

Delphi method is useful in terms of mobilization of stakeholders' expert knowledge for future predictions. The tool is also useful in terms of maintaining confidentiality and anonymity which facilitates participants to be more open and reveal their reasoning behind their predictions. An important consideration when using this method is to prevent that stakeholders' opinion are moulded by distorted feedback. Also it is very important to consider the number of experts and time constraints when opting for the Delphi method. The process might be potentially quick if experts are readily available and willing to participate, but it could also be time-consuming and result in insufficient representation of stakeholders` opinion. Therefore, the process requires a skilful facilitator who is unbiased and implements proper safeguards to deal with potential issues.

5 PARTICIPATORY SYSTEM MAPPING

5.1 System Mapping

5.1.1 Context and Purpose of the System Mapping Tool

System mapping (also known as market mapping) is an analysis tool that was initially developed by (Albu & Griffith, 2005) to closely examine the characteristics of the markets into which small farmers in developing countries might enter. The analysis consists of a description of three core elements: the business enabling environment; the market or value chain; and the supporting services (see below for further details).

In the EU FP7 projects (ENTTRANS, 2008) and (APRAISE, 2014) system mapping was used to identify with case study country stakeholders the system inefficiencies or blockages which would impede an acceleration of the development, deployment and diffusion of low

emission energy technologies identified for such sectors as energy production, energy consumption in buildings and residential dwellings, transport and waste.

System mapping is furthermore included in the toolbox for the Global Technology Needs Assessment (TNA) project (UNEP DTU Partnership, 2016). In the TNA project, the tool is used by developing countries for an analysis of the system for deployment or diffusion of a prioritised climate technology, identification of system barriers and elaboration on actions to clear these barriers. These actions are then included in a Technology Action Plan.

Within TRANSrisk, system mapping could be applied when describing the relevant system for a low emission pathway.

5.1.2 Analytical Focus and Theoretical Basis

The system mapping tool focuses on describing the relevant environment for introducing a commodity or technology or policy measure within a system, sector or country, as well as identifying what works and what does not work and why. It describes three layers of this environment:

- Enabling environment for the market, sector, or country, such as: infrastructure and policies, institutions and processes that shape the system environment (e.g. market demand, consumption trends, tax/subsidies and tariff regimes, investment policies, licensing, standards quality control and enforcements, etc.).
- The actors who operate in the market, sector, or country and who are affected by and/or play a role in the implementation of a commodity, technology or policy measure (e.g. primary producers, importer, traders, processors, input suppliers, energy companies, wholesalers, retailers and customers).
- The supporting services, such as legal, financial, quality control and technical support.

System mapping is based on the assumption that participatory processes can mobilise a broad range of (professional and/or anecdotal) knowledge available among stakeholders in a market, sector or country. System mapping uses participatory workshops with stakeholders using a skilled facilitator who can stimulate participants to share their knowledge and insights in a structured manner (e.g., enabling environment, market chain and supporting services). The process has a clear objective (e.g., explain whether a policy measure has been effective and efficient and explain the reasons why). The hypothesis is that the tool helps to bring to the fore both knowledge that can be measured as facts and perceptions that exist among stakeholders. Through the mapping process such facts can be shared among stakeholders and perceptions, where necessary, corrected based on new insights.

Additionally, the system map is a flexible tool that can capture various levels of complexities and can be used to analyse a specific area (see Figure 9) or multiple areas such as urban development (see Figure 11).

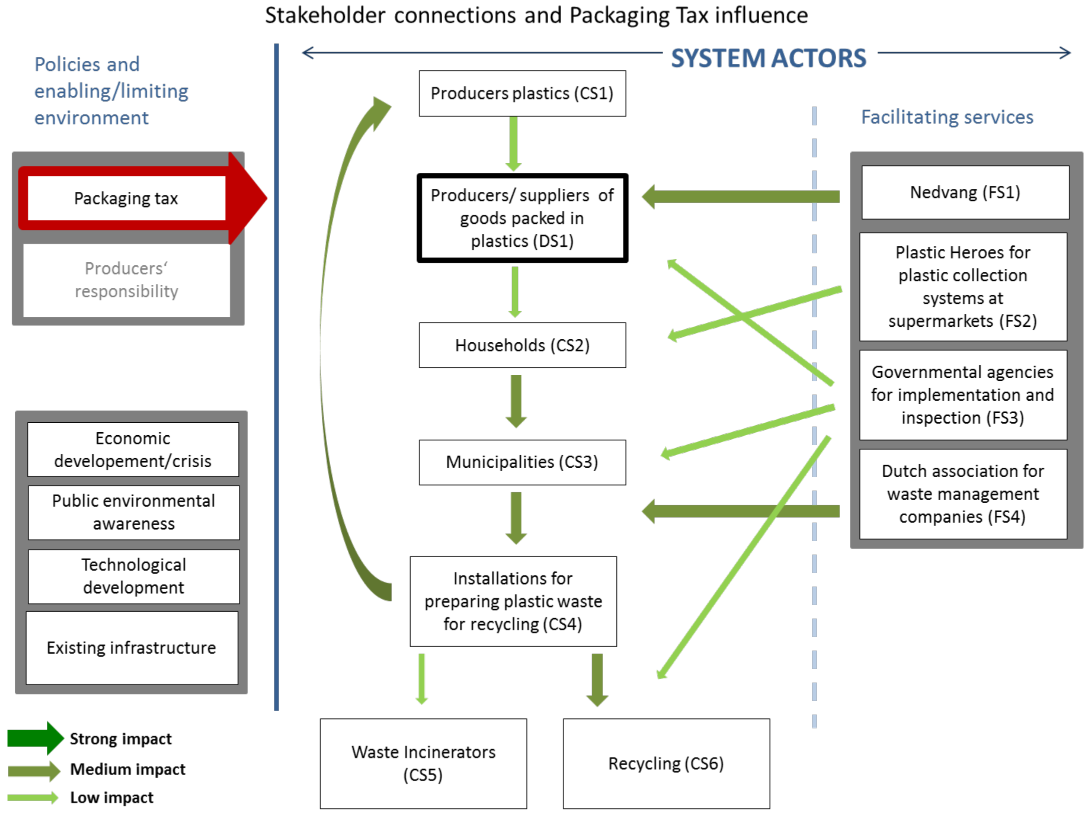
5.1.3 Sources, Types and Processing of Data

The main data source for system mapping is stakeholders' knowledge and (professional) experience. The data requirements also depend on how the mapping process is conducted. In cases where a system map is drawn with stakeholders from scratch, then data requirements beyond stakeholders' knowledge and insights are low. However, in cases where a basic map is prepared in advance by an expert team with further details to be added by stakeholders, upfront data gathering is required. The data needed in the 2nd case would consist of an overview of relevant structures, legislations, actors, services, etc. In terms of scale, system maps can be prepared at different scales (e.g. sectoral, regional, national, EU) and common elements from different maps can be scaled up across policy measures, sectors and countries.

Information provided by stakeholders is categorised by three levels as explained earlier (see example in the diagram below; which shows the levels horizontally from left to right). The arrows are drawn between the items and subsequently explained as a basis for evaluation (and their size can be used as an indication for how important a connection is).

System maps can be relatively straightforward (such as in the example of Figure 9) or more detailed (such as in Figure 11). The complexity and detail of the map, among others, depends on the complexity of the system analysed, but it can also depend on the extent to which stakeholders add elements to the map or decide to focus on highlights. Here, again, the role of the facilitator is important in order to conclude when a map is 'ready' or sufficiently complete for making decisions on actions to derive from the map.

Figure 9. System map for Dutch plastics recycling value chain



Based on the system map, an overview of barriers can be identified by stakeholders ('what are blockages in the system to successful implementation of a prioritised climate technology option?'). For instance, in Figure 11, the barriers are identified in red, while the enablers are identified in green. These can then be categorised, for example as follows:

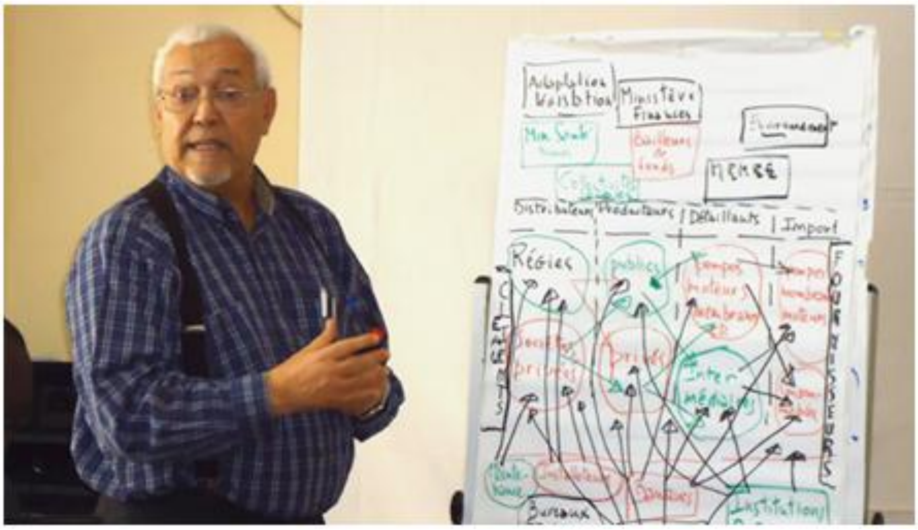
1. Economic and financial barriers.
2. Market failures.
3. Policy, legal and regulatory barriers.
4. Limited networking or networking failures.
5. Lack of institutional and organisational capacities.
6. Limited human capital, such as skills.
7. Social, cultural and behavioural barriers.
8. Limited awareness.
9. Actors with vested interests.
10. Other barriers.

Based on the discussion, further analysis of barriers can be performed in terms of:

1. What are the root causes of each barrier? For example, do we need to address the barrier or a more common root cause responsible for more barriers?
2. What are the most urgent barriers to address first?
3. What are possible actions to clear the barriers?

The interactions identified in the system map are primarily identified by stakeholder engagement. But prior to each stakeholder engagement, researchers can create an initial draft of the system map by identifying the key elements such as the enabling environment, the actors and the supporting services. The first draft of the system map can be presented to stakeholders and revised according to their inputs.

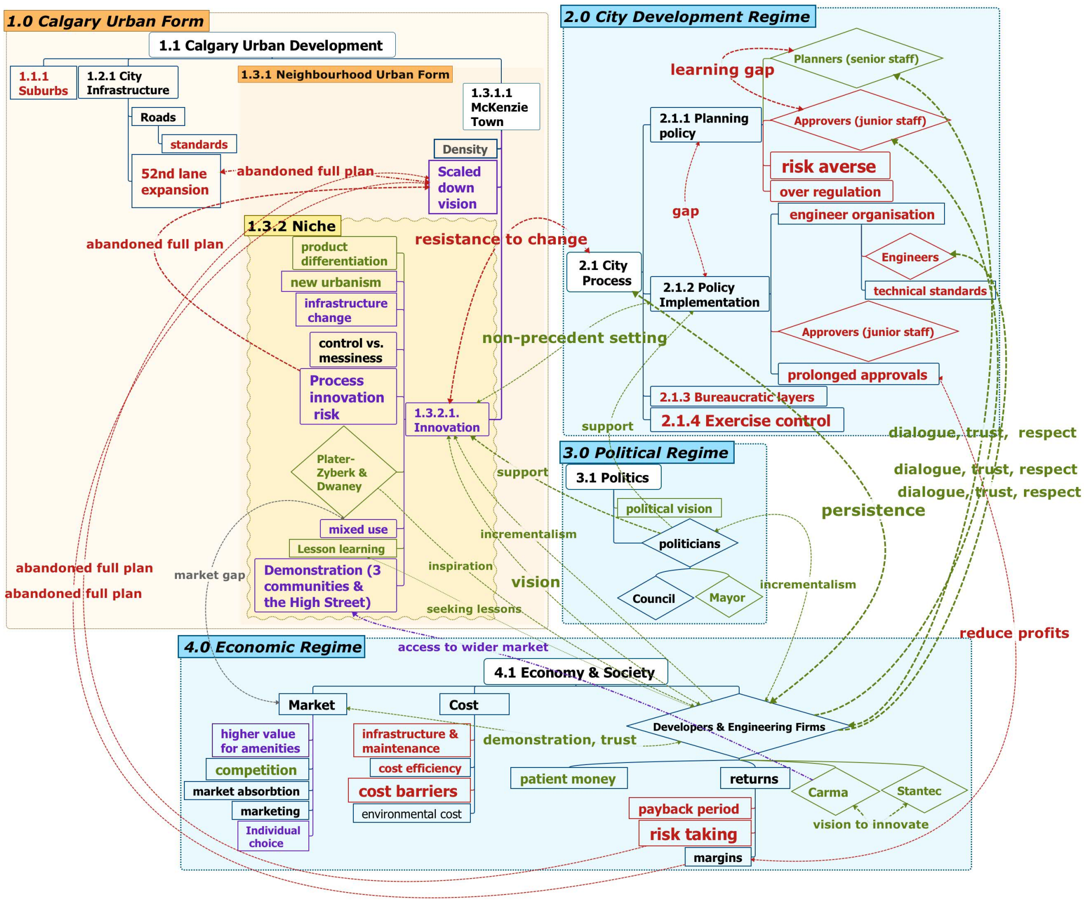
Figure 10. Example of system map, hand-written on flip-over



Source: (Gaast & Begg, 2012)

A simple version of a system map can be created using flip-overs with hand-written data (Figure 10) or Microsoft PowerPoint or another presentation/drawing software (see Figure 9). For more detailed system maps (see Figure 11), mind mapping software such as XMind or MindView are recommended. For the TRANSrisk case studies, partners are encouraged to use a mind mapping software for the final output, for which an internal on-line training workshop will be set up to train researchers. Mind mapping software is relatively user friendly and is more flexible (i.e. easier to revise) then hand drawn maps or maps produced in drawing software tools. The mind mapping software allow users to easily create elements, move sections of the mind map, as well as add in notes, pictures and web-links.

Figure 11. System map for Urban Development in Calgary, Canada



5.1.4 Applicability within TRANSrisk

The system map will provide a path dependent 'snapshot' of the system and illustrates the dynamic interactions between and across various groups of stakeholders (individuals and institutions). It also maps the interactions with the enabling environment including the policies and politics, technologies, the environment, the economy and society. These identified connections can be characterised by stakeholders in terms. For example, actor A delivers to actor B in the same value chain but can be impacted by natural resource constraints; actor C is a competitor of B and must compete in the international market etc. These characterisations are largely qualitative (strong collaboration, prohibitive competition, etc.) although some of these can be quantified (A sells to B for USD 200 million per year). A main output for TRANSrisk would be the identification of actions to improve the system so that the envisaged mitigation options can be successfully implemented for realisation of the pathway.

The system map can capture numerous interrelationship, but not all interactions have an equivalent impact. A qualitative indication of the interaction can be included by adding descriptive labels (as seen in Figure 11). For instance, the dotted connecting lines representing the interaction between the 'development firm' and institutional 'city

process' is labelled with the word 'persistence' to demonstrate the nature of the interaction. However, the degree or importance of the interaction is unclear. The width of lines or the size of the font can be increased to emphasise the importance of the interaction, but it can still be difficult to compare the strength of different interactions. Another method, known as Fuzzy Cognitive Mapping (see section 5.2), can be applied to systematically quantify the nature of interactions and to provide a further analysis on the cause-and-effect of interrelationships that are not captured in the system map. Fuzzy Cognitive Mapping applies the technique of characterising connections between actors and market elements as positive or negative quantitative values (e.g. on a scale from -1 to +1). This indicates whether an interaction has a negative or positive impact on the implementation of a mitigation option or the pathway as a whole, and how strong this impact is expected to be.

Relevant Work Packages for application of system mapping are Work Package 3 (case studies) and 6 (exploring innovation systems). In the case study analysis, system mapping can support the participatory analysis in the second step of the case study, when stakeholder will, among others, consider what systemic blockages exist for successful implementation of a prioritised low emission pathway for the country or sector. Using the mapping, based on the blockages identified, actions can be formulated to clear the blockages. Similarly, in Work Package 6, system mapping will be applicable to mapping the stakeholders in a relevant innovation system and describing their roles (including how they compete and/or collaborate and the interdependencies between stakeholders). This could possibly include some quantification of the relationships between actors in the map (e.g. how strongly do the stakeholders interact and is this interaction positive (e.g. collaboration) or negative (e.g. competition). As part of Work Package 6, the Stockholm Environment Institute (SEI) will apply system mapping in combination with quantification elements that are similar to Fuzzy Cognitive Mapping (see Section 5.2). This application will be further described in the Deliverables for Work Package 6.

5.1.5 Value of the Tool for Stakeholder Engagement

System mapping is useful in terms of mobilising stakeholders' expert knowledge. Therefore, upfront data requirements are relatively low. The tool is also useful in terms of addressing perceptions that may exist among stakeholders about a policy instrument. An important consideration when using the instrument of system mapping is to ensure that stakeholders' interests do not have a dominant impact on the result of the analysis. For instance, if stakeholders do not appreciate taxation as a policy instrument, their assessment of taxation to reach an environmental impact may be biased in terms of understating the policy opportunities and overstating the barriers. It would therefore be important that the stakeholder group is well balanced so that nobody would be able to steer the outcome toward their own interest. This also requires a skilful facilitator. As explained above, system mapping could in practice result in a qualitative assessment as stakeholder knowledge may not be easy to quantify.

5.2 Fuzzy Cognitive Mapping

5.2.1 Context and Purpose of the (original) Application of the Tool/Method

Fuzzy cognitive mapping is a qualitative modelling technique, introduced by Kosko (Kosko, 1986), that enables the analyst to not only capture the cause-and-effect relationships that emerge within a particular system but also assess how different interventions may affect that system. It is a stakeholder-driven analysis that consists of two core processes. The first comprises three intensive stakeholder engagement steps, during which a group of experts lists the system concepts, map them by identifying relations between them, and determines the level of causality that each relation represents. The second one consists of simulation sessions, during which a number of alternative options are stress-tested in order for comparisons between their impacts to be drawn.

Within TRANSrisk, fuzzy cognitive mapping will be applied in Work Package 7, in order to compare the impact of each alternative policy strategy for each case study. In countries where multiple sectors are examined, a cross-sectoral approach may be used instead.

5.2.2 Analytical Focus and Theoretical Basis

Fuzzy cognitive mapping focuses on describing a system (e.g. a specific sector in a country), by breaking it down into key concepts and interactions between these concepts, as perceived by stakeholders. As a qualitative modelling methodology without specific limitations with regard to its structure and content, it can describe any given system by incorporating aspects that other techniques cannot.

Fuzzy cognitive mapping is based on the hypothesis that many systems, which are otherwise hard or impossible to model due to difficulties in bringing together multi-disciplinary concepts and quantifying key system variables, can still be assessed by exploring experts' domain knowledge and experience. As implied by its name, the method is primarily based on Cognitive Mapping (Axelrod, 1976), a technique that aims to capture the expert's perception of a particular problem or domain in the form of a diagram. The method also incorporates elements from other scientific fields, namely Fuzzy Sets, Graph Theory and Neural Networks.

The technique can be used to further examine a set of successful policy strategies, a set of strategies that, according to quantitative model results, can promote the desired transition pathways for every examined country sector. It can do this by taking into account exclusively stakeholder-driven insights, and help select the best possible strategies for each case study.

The most important advantage of fuzzy cognitive mapping is that it does not depend on data availability, since every bit of information used to construct and, later, simulate a model comes from the stakeholders. As a result, any system can be modelled regardless of the size of the available data sets. Furthermore, since fuzzy cognitive maps are constructed solely on human expertise, they are highly flexible and not bound by limitations on their size and structure.

On the other hand, as a strictly qualitative and purely stakeholder-driven technique, fuzzy cognitive maps do not produce real-value estimations; they can only provide qualitative insight into the degree of effectiveness each set of policy measures can have with regard to the system under examination. This qualitative nature of the method has two drawbacks. Firstly, it can only be exploited for comparing alternatives, meaning that the extent to which each alternative can actually succeed into realising the desired end goal is unknown. Instead, the analyst can only draw conclusions over which alternative can produce better results compared to the others. Secondly, the time dimension is either arbitrarily or, in most cases, not at all defined.

These weaknesses can, however, be effectively overcome when implementing the method in TRANSrisk. Policy strategies assessed in the respective fuzzy cognitive maps will have already been evaluated through quantitative models, and deemed successful into promoting the desired transition pathways. In addition, an innovative approach will be employed in order to incorporate the time dimension to a certain extent.

5.2.3 Sources, Types and Processing of Data

The main data source for fuzzy cognitive mapping is the knowledge and expertise of the involved stakeholders. However, in an effort to link this qualitative technique with the results of quantitative models and other key tasks of the TRANSrisk project, stakeholder input will not be the sole source of data. The initial set of concepts that the interviewed stakeholders will be asked to elaborate on and extended for the purpose of mapping the system will comprise of:

- Key concepts from the extensive country case studies, policy strategies which will be deemed successful in the quantitative analyses that will take place prior to Work Package 7.
- Relevant risks and uncertainties that will be identified and assessed in Work Package 5.

Initially, a three-step stakeholder engagement process aims to elucidate the required information for mapping the system under examination. First, stakeholders are asked to list all of the perceived concepts that should be modelled. Then, they are asked to clarify how these concepts are connected to each other, e.g. whether each concept is perceived to be a cause and/or effect of every other concept. Finally, these perceived relationships are quantified in the same scale, between -1 and +1, in order to express how strongly each

concept affects the others, either positively or negatively. This quantification comes directly from the stakeholders, although a facilitating technique for assessing this information may be employed. Here stakeholders who find it easier to express their perception of the strength of these relations in linguistic terms, rather than numerical values, will be encourage to do so.

After the maps have been constructed, different simulations can be run for each policy option or set of policy options (i.e. policy strategies) of interest. In order to do so, a specific simulation driver function is selected for new values to be calculated at the end of every iteration, and a transfer function is employed so that these values are normalized at the desired scale.

After all different alternatives have been simulated, results can be compared in order to determine the optimal policy strategies for every country and/or sector.

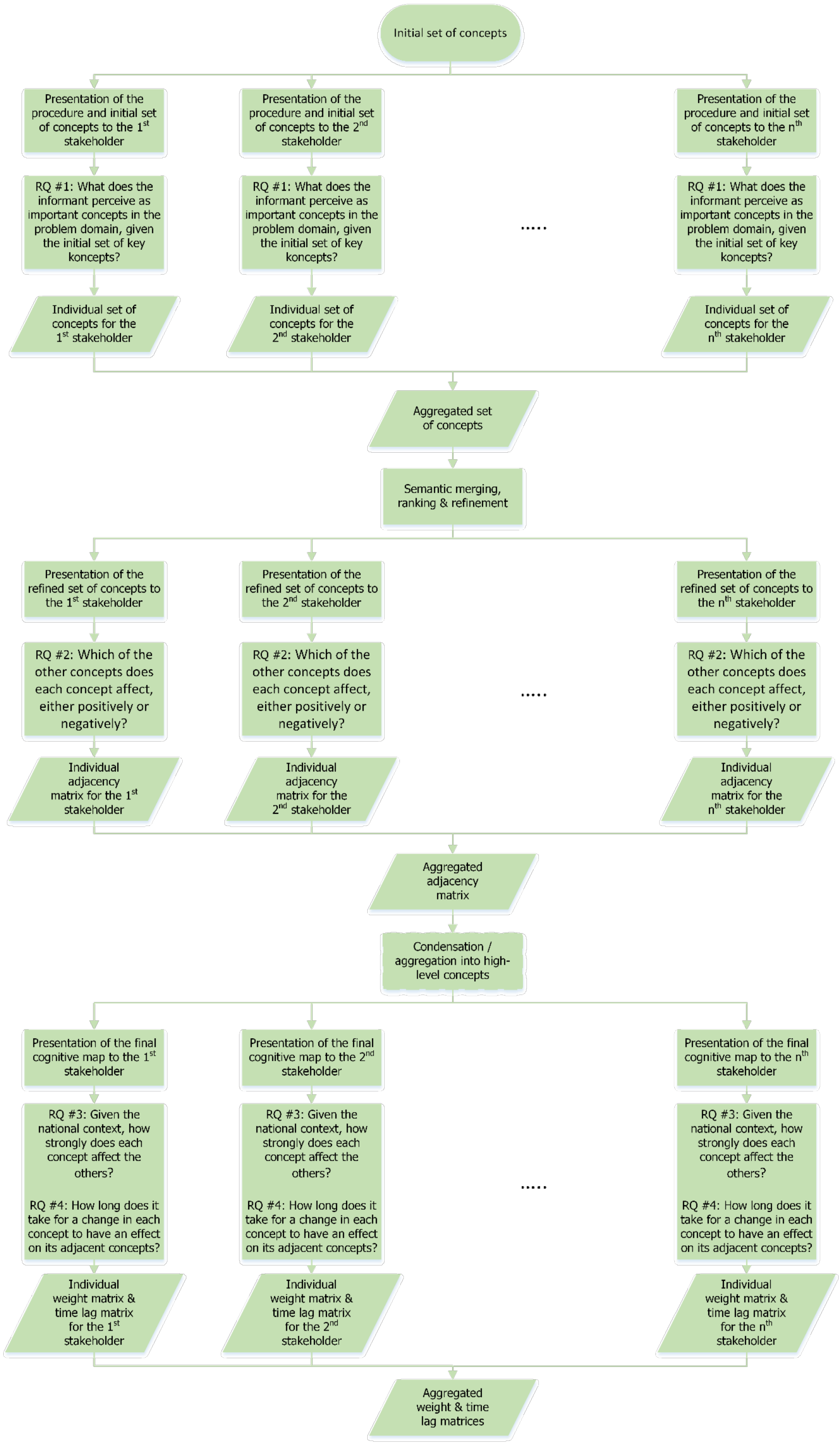
5.2.4 Applicability within TRANSrisk

This method will be applied in Work Package 7, and specifically in Task 7.1, in the aim of comparing different policy strategies and selecting the optimal ones among them, with regard to each country and/or country sector that is studied throughout Work Package 3.

5.2.5 Value of the Tool for Stakeholder Engagement

Fuzzy cognitive mapping is an effective approach for modelling systems that are hard or impossible to model otherwise, due to limited data availability and difficulty in quantifying variables or determining the exact relation between different concepts. Although this is not the case when assessing different climate mitigation policy options, as a large number of quantitative models have been constructed and used for this purpose, quantitative models and their results are usually too complex to either directly involve stakeholder insight or contribute to policy making. By considering only those policy strategies that can promote the desired transitions to low carbon economies and assessing them with fuzzy cognitive maps, stakeholders are not only enabled to provide their knowledge and experience in a friendly and structured way, but also offered the privilege of almost completely driving the simulation process. The obtained results are conclusions that are easier for policy makers to understand and trust. On the other hand, in order for a fuzzy cognitive map to be meaningful for non-analysts as well, its size should be limited. When a large number of stakeholders from various groups and of varying expertise are involved this is not always possible, since maps are exclusively built based on their input. This can be overcome either via a skilful facilitator (in the case of workshops), or using merging and aggregation techniques in between stakeholder steps in case questionnaires or interviews are employed.

Figure 12. The stakeholder engagement process in Fuzzy Cognitive Mapping



5.3 Agent-Based Modelling

5.3.1 Context and purpose of the (original) application of the tool/method

It is difficult to date the origins of Agent-Based Modelling (ABM) but most people cite Schelling's Segregation Model as a landmark paper (Schelling, 1971). Early works were far more abstract and theoretical compared to the many empirically-informed applications found today, and partly this is because of the availability of computing power and coding languages, which was previously a limiting factor.

It is similarly difficult to pin down purposes, however, a contrast is often made with other modelling methods that focus on predictions. (Epstein, 2008) notes 16 further uses of ABM other than predictions. Generally, the idea behind ABM is to understand a complex system (model) by generating it.

In our context, BSAM is an existing model that used to understand the Greek national power market in terms of the interactions among producers and consumers. A fuller review of the ABM literature is planned later in the TRANSrisk project (WP6).

Within TRANSrisk, ABM will be used to understand the micro, behavioural aspects of a technological innovation system showing how different model rules and policy pathways interact dynamically to produce different outcomes. These outcomes can be compared with some of the macro-variables used in the macro modelling. As such, within TRANSrisk, ABM contributes to bridging the gap between qualitative analytical tools (such as those described in this deliverable) and quantitative tools such as the macro models used in TRANSrisk.

5.3.2 Analytical focus and theoretical basis

ABM focuses on the individual actors and their interactions, both with each other and with the model environment. This could include many aspects of interest. There is not much restriction in terms of how ABMs are designed and which variables and rule-sets are included, which makes it a very flexible method.

Many ABMs inherit disciplinary assumptions, such as widespread use of utility functions in ABMs related to economics. On the other hand, there is a lack of social theory underlying ABM. Mainstream sociology has different concerns and methodological individualist approaches have not been popular for many years. However, there some ideas that are very relevant to ABM, such as Giddens structuration theory which similarly addresses how micro and macro are mutually inter-related.

ABM has also been used with stakeholders. Pioneering 'participatory' ABM is the French "Companion Modelling" group (Companion Modelling group, 2016), a name which refers to the exchange between "co-production of knowledge" and "support of collective decision-making processes". For them, the inclusion of stakeholders is meaningful because participatory modelling is about the "co-construction of conceptual models that represent visually multiple viewpoints and can be employed as mediating, discursive objects that promote collective learning processes." Benefits of participatory ABM are recognised by (Barreteau & Daniell, 2013) who discuss three types:

1. Quality of the simulation model per se.
2. Suitability of the simulation model for a given use.
3. Participation support – *i.e.* raising awareness and/or social learning about a situation.

As implied above, stakeholder engagement takes many forms and is important not just for elucidating data. That said, ABM offers a way, when used alongside other methods, to integrate more detailed understandings into TRANSrisk modelling work. ABM will use qualitative information as well as quantitative information. For example, ABM can be linked with participatory mapping tools such as described above in this deliverable. Hence, ABM is a method that addresses the trade-off between the desirable formal characteristics of qualitative data that are useful in modelling, and the diversity of responses and considerable detail elicited using qualitative methods.

A main use of ABM (along with other methods) would be for understanding in much more detail the potential consequences of different transition pathways. Another potential role is to be used with Portfolio Analysis (TRANSrisk Task 7.2), in terms of supplying information about the evaluation of performance and risk of different options and the combined portfolios.

The flexibility of ABM does not mean that is always a good choice. It has practical and conceptual difficulties. The models are difficult to understand and validate. ABM is time and resource intensive, and is fair to say that these difficulties are not generally compensated by high rate of model uptake and practical use.

5.3.3 Sources, types and processing of data

The data requirements for ABM are high, but much work has also been undertaken in developing methods for low data situations. There are various potential sources. According to (Poteete, Janssen, & Ostrom, 2010, p. 196) empirical inputs can be obtained from: (1) stylised facts, (2) laboratory or field behavioural experiments, (3) role games, or (4) case studies. These data would usually be quantitative, with the data collection methods being linked to appropriate data analysis methods, such as parameter estimation, cluster/factor analysis, specifying indicator weightings. However, as described in the section above, ABM can also be linked with methods for eliciting and using qualitative information.

ABM can be described as a 'generative' method. Agents are endowed with some initial data and rules (where possible informed by empirical sources). Running the model 'generates' data at subsequent time steps. Normally both the initialisation and the simulation also include some stochastic elements. Much of the work involves analysing the simulation data which is produced simultaneously at different levels of analysis. Without going into detail about all of the different techniques here, this particularly involves time series data. Conclusions are drawn about the behaviour of the model, and then there is a final 'inference' step back to the real system – and in this it is important to avoid 'overinterpreting' observations about the model.

5.3.4 Applicability within TRANSrisk

A main use of ABM (along with other methods) would be for understanding in much more detail the potential consequences of different transition pathways (in WP3 for the case studies and WP6 on innovation). Another potential role is to be used with Portfolio Analysis (Task 7.2) in terms of supplying information about the evaluation of performance and risk of different options and the combined portfolios.

Like any method, ABM has conditions of applicability. As mentioned above, there are many drawbacks, and often using another method will be a better choice. The trade-off in potential benefits against difficulty of ABM is most likely to be worthwhile if there are important interactions that must be included in a disaggregated way.

5.3.5 Value of the tool for stakeholder engagement

As a stakeholder engagement tool ABM has demonstrated its value in many natural resources management contexts. A literature review on use in technological innovation systems and climate/energy policy would provide a useful indication of the outlook for applying ABM in these areas.

ABM is often identified as a highly promising method for its flexibility, its ability to link micro and macro perspectives, and to look at dynamic consequences of policies and responses to policies. However, data requirements and resource requirements for ABM are high, so it will be necessary to use it very selectively in TRANSrisk.

6 Overview of Applicability of Stakeholder Engagement Tools in TRANSrisk

The table below summarises the tools described in this deliverable, including the required inputs and expected outputs.

Table 2. Summary of Qualitative Tool Application in TRANSrisk

Tool	Power and Interest Matrix	
WP(s)	**Description**	**Inputs and expected outputs**
2, 3, 4, 5, 6, 7, 8	In Task 2.3, stakeholders are identified for the case study analysis in WP3. A first distinction is between stakeholders that are generalists and those who have more specific knowledge. When communicating the case study results to decision makers, higher-level key player will need to be addressed. In WP4, international organisation stakeholders will be consulted. These stakeholders are not necessarily key players, but their knowledge and viewpoints are important for developing regional and global scenarios. In WP5, stakeholders will be engaged for risk analysis, for which a balanced representation of stakeholders from the matrix cells is envisaged. In WP 6, stakeholders from all matrix cells will be involved in the innovation system analysis. This widening is recommended as all stakeholders, irrespective of their influence on decision-making, are important for understanding an innovation system. In WP7, stakeholders from different cells will be consulted for testing the semi-quantitative tools, such as Fuzzy Cognitive Mapping.	*Inputs*: - Identified stakeholders from the networks of TRANSrisk partners. - Description of each stakeholder. *Expected outputs*: - Characterisation of stakeholders in the matrix.

	In WP8, the dissemination strategy will need to consider the different profiles of stakeholders from each cell for effective, tailored dissemination of results.	
Tool	**H-Form**	
WP(s)	**Description**	**Inputs and expected outputs**
3	H-Form can be used for organising a discussion around research questions and categorising the answers provided by stakeholders. In the case study workflow, H-Form can be particularly useful during the first step when 'generalists' and 'frontrunners' are consulted with a first set of research questions.	*Inputs*: - Opinions, viewpoints, and tacit knowledge of stakeholders. - Skilled facilitator. *Expected outputs*: - Set of answers to a research question - Answers grouped as 'negative' and 'positive'. - Eventually, a common answer.
Tool	**Multi Criteria Decision Analysis (MCDA)**	
WP(s)	**Description**	**Inputs and expected outputs**
3, 5, 7	In WP3, MCDA will be used to help stakeholders prioritise options for climate change mitigation in their country context, in terms of achieving the strongest combined contribution to economic, social, environmental and climate benefits, thereby possibly considering affordability. In WP5, MCDA will be used for ranking climate change mitigation options based on how stakeholders value benefits of options against potential risks related to each option. For example, how will stakeholders value an option that potentially delivers the strongest benefits, but is also surrounded by several risks? Will this stimulate stakeholders to prefer a less beneficial, but also less risky option?	*Inputs*: - Stakeholder preferences and knowledge. - Criteria for assessment. - Overview options to be considered (possibly with factsheets). - Skilled facilitator. *Expected outputs*: - Scores and weights for options for mitigation to enable ranking of options. - Portfolio of prioritised options for climate change mitigation.

	In WP7, MCDA will be tested in a semi-quantified application (OMIMS, see below).	
Tool	**Online Multidisciplinary Information Management Software** (OMIMS)	
WP(s)	**Description**	**Inputs and expected outputs**
3, 5, 7	The OMIMS tool could be applied, after appropriate customisation, in stakeholder-driven tasks, such as Task 5.4, Task 5.5 and Task 7.1, but it could also be applied for evaluating possible policy instruments in WP 3 that could be later incorporated into the quantitative models.	*Inputs*: - Any heterogeneous information that must be aggregated in the context of TRANSrisk, either provided by stakeholders or not. - Decision variables. - Options for mitigation. *Expected outputs*: - Unified information in similar terms enabling comparison of options. - Selection of options for mitigation.
Tool	**Delphi tool**	
WP(s)	**Description**	**Inputs and expected outputs**
3	Especially, the during first stage of TRANSrisk case study analysis, Delphi can be used for inspiring stakeholders to take a wider, longer term perspective on preferred pathway developments, prioritised options for climate change mitigation, and suitable policy instruments.	*Inputs*: - Stakeholders' knowledge and (professional) experience. - Both qualitative (open questions) and quantitative data (for statistical analysis). *Expected outputs*: - Expected impact of environmental policies and climate change mitigation options. - Agreements among stakeholders on a longer term vision or decision-making with a longer-term perspective.

Tool	System Mapping	
WP(s)	**Description**	**Inputs and expected outputs**
3, 6	In the case study analysis in WP3 and 6, system mapping will be used to explore the markets or systems for implementation of prioritised options for climate change mitigation as part of a pathway. This enables identification of barriers and system blockages to this implementation and innovation in general, and selection of actions to clear these.	*Inputs*: - Stakeholders' knowledge and experience. - Facilitator. *Expected outputs*: - Overview map of enabling environment for mitigation option, system) actors and their interactions. - Overview of barriers and enablers (to clear system barriers).
Tool	**Fuzzy Cognitive Mapping**	
WP(s)	**Description**	**Inputs and expected outputs**
7	Fuzzy cognitive mapping will be applied in WP 7, in order to compare the impact of each alternative policy strategy for each case study; in countries where multiple sectors are examined, a cross-sectoral approach may be used instead.	*Inputs*: - Knowledge and expertise of the involved stakeholders. - Policy strategies deemed successful in the quantitative analyses in TRANSrisk. - Risks and uncertainties (from WP5). - Facilitating technique. *Expected outputs*: - Simulations run for each policy option or set of policy options. - Comparison of results for selection of priority strategy.

Tool	Agent-based modelling (ABM)	
WP(s)	**Description**	**Inputs and expected outputs**
6, 7	In WP6, ABM will be used for deepening the understanding of how actors (agents) operate within an innovation system, including how they interact with other actors. While focussing on the micro-level of actors, it enables quantification of directions of interactions (compete or collaborate) and the strength of actions and interactions. Another potential role is to use ABM with Portfolio Analysis in Task 7.2. in terms of supplying information about the evaluation of performance and risk of different options and the combined portfolios.	*Inputs*: - Data requirements for ABM are high, to be obtained from: (1) stylised facts; (2) laboratory or field behavioural experiments; (3) role games; or (4) case studies. *Expected outputs*: - Running the model 'generates' data at subsequent time steps. - Conclusions about behaviour of actors in the model environment. - 'Inference' step back from model to real system.

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